

# Low Temperature Shape Memory Alloys for Adaptive, Autonomous Systems Project

Center Innovation Fund: KSC CIF Program | Space Technology Mission Directorate (STMD)



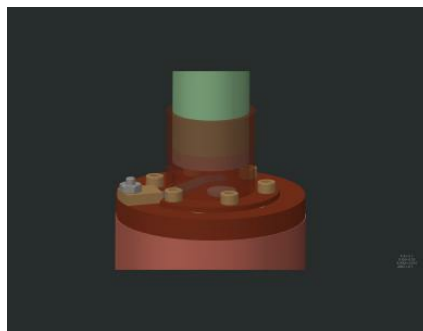
## ABSTRACT

The objective of this joint activity between Kennedy Space Center (KSC) and Glenn Research Center (GRC) is to develop and evaluate the applicability of 2-way SMAs in proof-of-concept, low-temperature adaptive autonomous systems. As part of this low technology readiness (TRL) activity, we will develop and train low-temperature novel, 2-way shape memory alloys (SMAs) with actuation temperatures ranging from 0°C to -150 °C. These experimental alloys will also be preliminary tested to evaluate their performance parameters and transformation (actuation) temperatures in low- temperature or cryogenic adaptive proof-of-concept systems. The challenge will be in the development, design, and training of the alloys for 2-way actuation at those temperatures.

## ANTICIPATED BENEFITS

### To NASA funded missions:

Significant benefit will be gained in expanding the knowledge base and novel innovation at multiple NASA centers in low-temperature SMA technologies. KSC's efforts focus on *SMA Adaptive Materials Systems Concepts and Designs* and GRC's efforts focus on *Novel Low-temperature Alloy Designs*. 2-way cryogenic temperature SMAs open new areas of applications in space and commercial aerospace (e.g. adaptive umbilical connectors (thermal and mechanical) which use surrounding environments to add multi-functionality). It is expected systems like this would allow for more robust operations in cryogenic storage and transfer systems and in-situ resource utilization for space exploration. It is expected technology success could result in game changing results for use of low temperature SMAs in adaptive, smart thermal/mechanical systems.

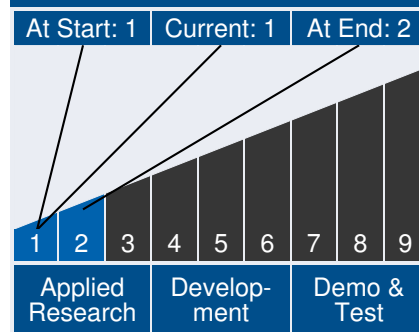


Cryogenic training apparatus design for low temperature, two-way shape memory alloys

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## Technology Maturity



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## To NASA unfunded & planned missions:

Aligns with the following NASA Strategic Initiatives:

-Strategic Space Technology Investment Plan (SSTIP) Strategic Goal 3: technology investment framework under core technology investment and adjacent technologies, light weight structures and autonomous control, and surface systems.

- NASA Roadmap technologies areas (TA) alignment TA12.2.1.4 Environment; TA12.2.2.1 Lightweight Concepts, Shape Morphing Materials; TA12.2.2.5 Innovative, Multi-functional Concepts, Adaptive/smart Structures; TA14.2.1 Cryogenic Systems; TA2.2.1.2 In-Space Propulsion, Liquid Cryogenic; TA2.2.4.2 Propellant Storage & Transfer; and TA13.1.1 Distribution, Storage and Conservation of Fluids.

-NASA Space Technology Grand Challenges – Space Colonization

Development of this technology also aligns with the Office of Science and Technology Policy (OSTP) focus area: Development of New Foundational Technologies to Reduce Future Costs Across NASA, Expand Opportunities, and Grow the American Economy.

## To the commercial space industry:

Advancing development and NASA intellectual property in the area of multifunctional materials for cryogenic thermal control, autonomous systems, and technologies for umbilical and surface systems can result in technology transfer and benefits to the commercial space industry.

## To the nation:

This technology would have multiple non-NASA benefits and commercial applications in the cryogenic storage and transfer, medical, and energy conservation industries. This technology

## Management Team

### Program Executive:

- John Falker

### Program Manager:

- Nancy Zeitlin

### Project Manager:

- Martha Williams

### Principal Investigator:

- Martha Williams

### Co-Investigators:

- Othmane Benafan
- James Fesmire

## Technology Areas

### Primary Technology Area:

Materials, Structures, Mechanical Systems & Manufacturing (TA 12)

### Secondary Technology Area:

Thermal Management Systems (TA 14)

### Other Technology Areas:

- In-Space Propulsion Technologies (TA 2)
- Human Exploration Destination Systems (TA 7)
- Ground & Launch Systems Processing (TA 13)

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could have applications in use of robotic systems in extreme environments. Benefits to the Department of Energy and military are expected and potential benefits to Homeland Security.

## DETAILED DESCRIPTION

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The feasibility of using SMAs to provide switchable thermal systems has been previously demonstrated by taking advantage of the 1- or 2-way actuation properties of SMAs, allowing a system to switch between a thermally insulative to a conductive state by actuation of the SMA at a preset temperature. However, the alloys designed or commercially available and tested to date had actuation temperatures above room temperature (65–95 °C). Technology needs still exists for autonomous actuation at cryogenic temperatures. The GRC portion of the research work is being leveraged to address such technology gaps in low-temperature SMA compositions and covers a broad chemistry of binary, ternary and quaternary alloys with temperature-induced actuation capabilities below 0 °C. Experimental alloys with elemental constituents encompassing Fe, Co, Cr, Hf, Cu and Zr added to the base NiTi alloy are explored and downselected. The new alloys are cryogenic trained for 2-way actuation for potential utilization in novel designs developed by KSC.

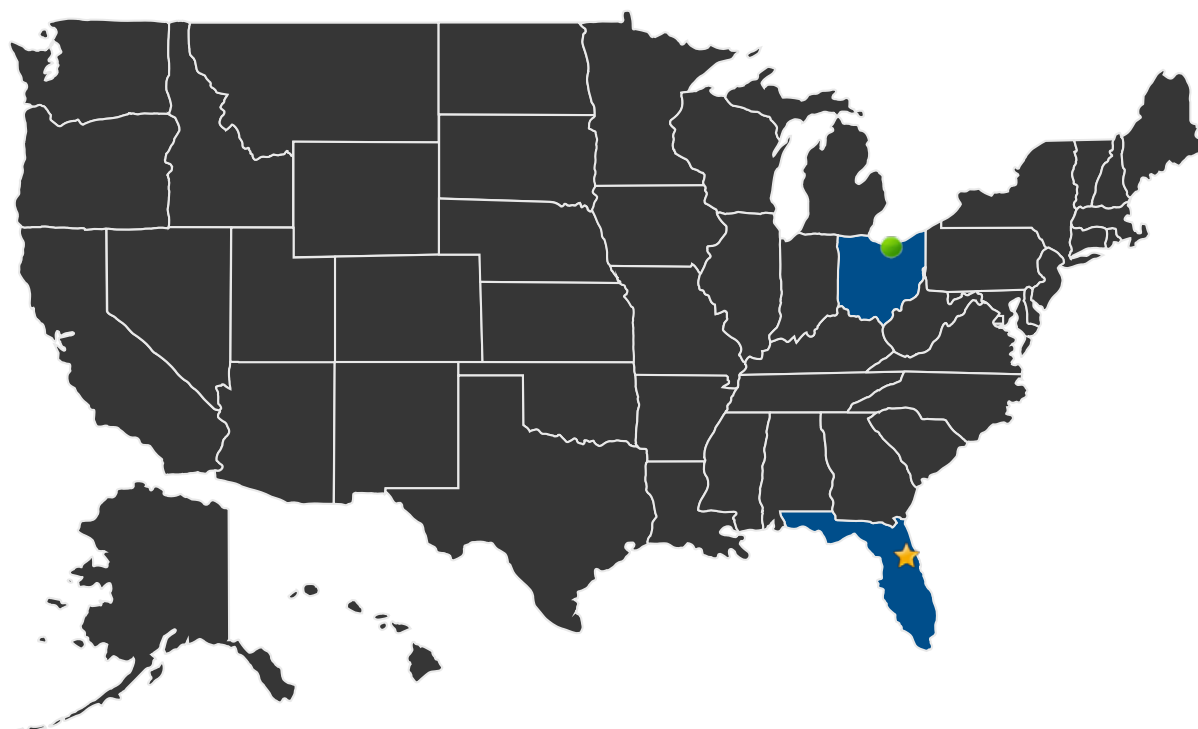
Completed Project (2014 - 2015)

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## U.S. LOCATIONS WORKING ON THIS PROJECT



■ U.S. States With Work

★ **Lead Center:**  
Kennedy Space Center

● **Supporting Centers:**

- Glenn Research Center

### Contributing Partners:

- The University of Florida
- University of Central Florida

**TechPort**

For more information visit [techport.nasa.gov](http://techport.nasa.gov)

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Some NASA technology projects are smaller (for example SBIR/STTR, NIAC and Center Innovation Fund), and will have less content than other, larger projects. Newly created projects may not yet have detailed project information.

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## DETAILS FOR TECHNOLOGY 1

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### Technology Title

Low temperature SMAs for Adaptive Autonomous Systems

### Technology Description

This technology is categorized as a material for ground support or mission operations

This technology allows for the design of proof-of-concept thermal/mechanical, adaptive systems that are applicable to autonomous systems and other cryogenic storage and transfer systems. As part of this technology development, GRC's novel shape memory alloys are being utilized and KSC is developing novel low-temperature 2-way training mechanisms and systems (backward and forward, shape-shift spontaneously to accommodate changing operating conditions) using newly designed or modified cryocooler-based apparatuses. These novel low temperature SMAs are being preliminary evaluated in a KSC developed proof-of-concept breadboard design for an adaptive thermal system.

### Capabilities Provided

Shape Memory Alloys (SMAs) are a unique class of metal alloys that can recover apparent permanent strains when they are heated above a certain temperature. The SMAs have two stable phases - the high-temperature phase, called *austenite* and the low-temperature phase, called *martensite*. Experimental alloys with elemental constituents encompassing Fe, Cr, and Hf added to base NiTi alloy were explored to lower the martensite transformation temperatures below or near 0 °C. Preliminary results indicate that at least one or more of the experimental alloys have shown two-way actuation at low temperatures and have preliminary demonstrated adaptive behavior in a low-fidelity proof-of-concept design. Also important capabilities in the design of cryogenic training apparatus and training mechanisms have been developed. These capabilities and types of multi-functional, adaptive thermal material/systems could allow for overall reduction in complexity of system architectures and meet important technology gaps identified in the area of multi-functional and adaptive materials.

### Potential Applications

Applications include innovative, multi-functional materials for in-space propulsion, cryogenic storage and transfer for ground and space systems, space habitation systems, and in-situ resource utilization for space exploration. Applications for this technology are anticipated beyond NASA in

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industries such as cryogenics, satellites, and medical. Significant knowledge base has been established in the development of low- temperature SMA and in the cryogenic training mechanisms, methodologies and design of apparatuses using cryocoolers, which will be beneficial to the SMA Scientific community.

## Performance Metrics

Metric	Unit	Quantity
2-way actuation at below zero degree centigrade		